PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2001-210867
(43)Date of publication of application : 03.08.2001

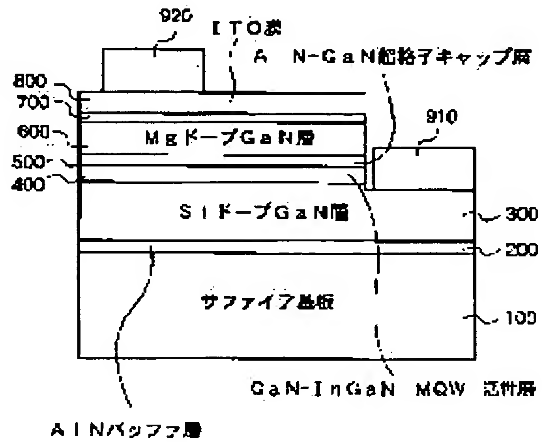
(51)Int.Cl. H01L 33/00
H01L 21/28
H01L 21/285
H01S 5/343

(21)Application number : 2000-014390
(22)Date of filing : 24.01.2000

(71)Applicant : SEIWA ELECTRIC MFG CO LTD
(72)Inventor : TOKUJI SHIGEKAZU
YAMAJI TAHEI

(54) GALLIUM NITRIDE SEMICONDUCTOR LIGHT EMITTING ELEMENT AND MANUFACTURING METHOD THEREFOR

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a gallium nitride semiconductor light emitting element which is superior in mechanical strength, which is not easily deteriorated even in high temperature/high humidity environment, and which has the high take-out efficiency of light to an outer part.
SOLUTION: A gallium nitride semiconductor light emitting element is provided, having an ITO film whose film thickness is 100 Å or more as a current diffusion layer, where at least its first layer is formed on a P-type GaN semiconductor layer by a vacuum vapor deposition method.



LEGAL STATUS

[Date of request for examination]	25.01.2000
[Date of sending the examiner's decision of rejection]	23.07.2002
[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]	
[Date of final disposal for application]	
[Patent number]	3394488
[Date of registration]	31.01.2003
[Number of appeal against examiner's decision of rejection]	2002-15979
[Date of requesting appeal against examiner's decision of rejection]	22.08.2002
[Date of extinction of right]	

CLAIMS

[Claim(s)]

[Claim 1] A gallium nitride system semiconductor light emitting device characterized by having a transparence electric conduction film by which an eye was further formed at least by methods other than the sputtering method as a current diffusion layer on a P type GaN semiconductor layer in a gallium nitride system semiconductor light emitting device.

[Claim 2] A gallium nitride system semiconductor light emitting device according to claim 1 to which methods other than said sputtering method are characterized by being either a vacuum deposition method, the laser ablation method or a sol gel process.

[Claim 3] It is the gallium nitride system semiconductor light emitting device according to claim 1 or 2 characterized by thing of said current diffusion shell which an eye consists of either an ITO film, a tin oxide film, an indium oxide film or a zinc-oxide film further.

[Claim 4] An eye is a gallium nitride system semiconductor light emitting device according to claim 1, 2, or 3 to which it is characterized by thickness being [of said current diffusion shell] about 100A or more much more.

[Claim 5] It is the ITO film of said current diffusion layer in which an eye was further formed by vacuum deposition method, and this ITO film is SnO_2. A gallium nitride system semiconductor light emitting device according to claim 1 characterized by being 2 - 20%.

[Claim 6] An eye is a gallium nitride system semiconductor light emitting device according to claim 5 to which thickness is about 100A or more much more, and it is characterized by thing of said current diffusion layer done for the laminating of the ITO film by the sputtering method on it.

[Claim 7] A manufacture method of a gallium nitride system semiconductor light emitting device characterized by an eye forming a transparence electric conduction film by methods other than the sputtering method further at least as a current diffusion layer on a P type GaN semiconductor layer in a manufacture method of a gallium nitride system semiconductor light emitting device.

[Claim 8] A manufacture method of a gallium nitride system semiconductor light emitting device according to claim 7 that methods other than said sputtering method are characterized by being either a vacuum deposition method, the laser ablation method or a sol gel process.

[Claim 9] Said transparence electric conduction film is the manufacture method of a gallium nitride system semiconductor light emitting device according to claim 7 or 8 characterized by consisting of either an ITO film, a tin oxide film, an indium oxide film or a zinc-oxide film.

[Claim 10] It sets to a manufacture method of a gallium nitride system semiconductor light emitting device, and is SnO_2 by vacuum deposition method on a P type GaN semiconductor layer. A manufacture method of a gallium nitride system semiconductor light emitting device characterized by considering as a transparence electric conduction film by heat-treating after forming an ITO film which is 2 - 20% at a room temperature.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] This invention relates to the gallium nitride system semiconductor light emitting device of the light emitting diode for which light can be emitted blue, and laser diode, and the manufacture method of this gallium nitride system semiconductor light emitting device.
[0002]
[Description of the Prior Art] A gallium nitride system semiconductor (GaN system semiconductor) realizes blue luminescence which was difficult from sometime past, and is used for a light emitting diode element. A P type GaN system semiconductor has very large specific resistance about 2ohmcm and compared with other semiconductors, although it is realizable. In addition, in a P type GaAs system semiconductor mold, what has as low specific resistance as about 0.001ohmcm is obtained simply.
[0003]
[Problem(s) to be Solved by the Invention] Therefore, if the metal electrode of bonding pad combination like the conventional light emitting diode is attached, only the amount of [of the metal electrode] true lower part will emit light. Since it is furthermore interrupted by the metal electrode, the light made to take out will become very small. Although it is going to make [many] light which can be taken out there using the translucent auxiliary electrode which consists for example, of a nickel/Au thin film, since a nickel/Au thin film is also about 50% of permeability, the ejection effectiveness to the exterior of light is not so high. Moreover, about 100A and since the thickness of a nickel/Au thin film is very thin, a mechanical strength's is weak, and it has troubles, such as deterioration under environment, whenever [high-humidity/temperature].
[0004] It was originated in view of the above-mentioned situation, and this invention is excellent in a mechanical strength, cannot deteriorate easily under environment whenever [high-humidity/temperature], and aims at offering the high gallium nitride system semiconductor light emitting device and its manufacture method of ejection effectiveness to the exterior of light.
[0005]
[Means for Solving the Problem] A gallium nitride system semiconductor light emitting device concerning this invention forms a transparence electric conduction film for an eye by methods other than the sputtering method further at least as a current diffusion layer on a P type GaN semiconductor layer.
[0006] Moreover, it is desirable for methods other than said sputtering method to be either a vacuum deposition method, the laser ablation method or a sol gel process.
[0007] Furthermore, as for said transparence electric conduction film, it is desirable to consist of either an ITO film, a tin oxide film, an indium oxide film or a zinc-oxide film.
[0008]
[Embodiment of the Invention] The rough cross section of the gallium nitride system semiconductor light emitting device which drawing 1 requires for the gestalt of operation of the 1st of this invention, and drawing 2 are the rough cross sections of the gallium nitride system semiconductor light emitting device concerning the gestalt of operation of the 3rd of this invention.
[0009] First, the conditions demanded as a current diffusion layer for the P type GaN semiconductor layers of a GaN system semiconductor light emitting device ** It is mentioned that adhesion with a P type GaN semiconductor layer is excellent, that contact resistance with a ** P type GaN semiconductor layer is small, not making a P type GaN semiconductor layer form into high resistance at the time of ** film formation, that what has it can diffuse current, that the permeability of ** light is high, etc. [low ** resistivity and thin]
[0010] Then, permeability is high, conductivity is also good, and if it is the ITO film already put in practical use in the liquid crystal display panel etc., it will be thought that said condition ** and ** can be satisfied. However, by the sputtering method generally used as the technique of forming an ITO film now, although it could be satisfied, probably because the P type GaN semiconductor layer exposed to the high energy condition of the plasma received damage and said condition ** had high contact resistance, it was not able to obtain the element of low operating voltage.
[0011] When the ITO film was formed with the sol gel process, although the specific resistance of the ITO film itself was higher than the ITO film formed by the sputtering method 10 or more times, it was able to obtain the element with low operating voltage. From this experimental result, the contact resistance between the P type GaN semiconductor layer of said condition ** and an ITO film surmised whether the low thing would be made.
[0012] Then, it was considered that the sputtering method is not made to satisfy said condition **. Then, when the formation method of the sufficiently low ITO film of specific resistance was considered except the sputtering method, the possible thing became clear with the vacuum deposition method. It has checked that the ITO film formed with this vacuum deposition method had sufficiently low operating voltage.
[0013] Moreover, when thickness forms ITO film about 100A or more by the vacuum deposition film and formed the small ITO film of specific resistance further by the sputtering method on it, what has operating voltage low enough was able to be obtained.

[0014] Below, the fact which actually became clear by experiment is explained.
[0015] Next, the manufacture method of the gallium nitride system semiconductor light emitting device concerning the gestalt of operation of the 1st of this invention is explained. First, thermal cleaning is given to silicon on sapphire 100. That is, silicon on sapphire 100 is cleaned by heating at 1050 degrees C, supplying hydrogen within a reduced pressure MOCVD system (reduced pressure organic metal vapor growth equipment).

[0016] Next, the temperature of silicon on sapphire 100 is reduced even at 510 degrees C, ammonia and trimethylaluminum are supplied by making nitrogen and hydrogen into carrier gas, and the low-temperature AlN buffer layer 200 is formed in the surface of silicon on sapphire 100. This AlN buffer layer 200 is about 200A.
[0017] Next, the temperature of silicon on sapphire 100 is raised at 1000 degrees C, and ammonia and trimethylgallium are passed using said carrier gas. At this time, the silicon as an N type impurity is used for coincidence, and about 1.2 micrometers of Si dope GaN layers 300 which are N type GaN are grown up.
[0018] Next, about 400A of barrier layers 400 which consist of a multiplex quantum well (MQW) of N type GaN and N type InGaN is grown up on the Si dope GaN layer 300, passing trimethylindium intermittently.
[0019] Furthermore, the cap layer 500 which consists of superlattice of AlN and P type GaN is grown up on said barrier layer 400, using temperature of silicon on sapphire 100 as 950 degrees C. This cap layer 500 is about 200A in thickness.
[0020] Next, magnesium is added to carrier gas as an impurity, and about 0.2 micrometers of Mg dope GaN layers 600 are grown up.
[0021] Next, temperature of silicon on sapphire 100 is made into 800 degrees C, and the pressure in a reduced pressure MOCVD system is set to 6650Pa (50torr). The ambient atmosphere in a reduced pressure MOCVD system is promptly changed from the ambient atmosphere of the mixed gas which can come, simultaneously contains hydrogen atoms, such as ammonia, to the nitrogen gas which is inert gas.
[0022] And using nitrogen gas as carrier gas, trimethyl zinc is passed and the Zn film 700 whose thickness is dozens of A is formed. And the temperature of silicon on sapphire 100 is reduced at about 100 degrees C or less under the condition of this as, i.e., nitrogen-gas-atmosphere mind.
[0023] Then, the silicon on sapphire 100 in which even the Zn film 700 was formed is put into a vacuum evaporation system, and it is SnO2. With an electron gun, 10% of ITO is heated, is evaporated, and thickness forms the about 0.5micromITO film 800 on the Zn film 700. Temperature of the silicon on sapphire 100 in this case was made into 200 degrees C.
[0024] Thus, it was checked that the specific resistance of the formed ITO film 800 has become below 0.0005-ohmcm.
[0025] Next, dry etching of some ITO films 800 is carried out, and a part of Si dope GaN layer 300 is exposed. The N type electrode 910 is formed in this exposed Si dope GaN layer 300, and the P type electrode 920 is formed in said some of ITO films 800. these two electrodes 910 and 920 -- a Ti/Au thin film -- about 500A/-- about 5000A is vapor-deposited.
[0026] Thus, the manufactured gallium nitride system semiconductor light emitting device had operating voltage very as low as 3.5V with 20mA current, and improving about 60% rather than the translucent auxiliary electrode with which the ejection effectiveness to the exterior of light also consists of the conventional nickel/Au thin film was checked.
[0027] By the manufacture method of the gallium nitride system semiconductor light emitting device concerning the gestalt of the 1st operation mentioned above, when forming the ITO film 800, temperature of silicon on sapphire 100 was made into 200 degrees C, but in case the ITO film 800 is formed, it is also possible to make temperature of silicon on sapphire 100 into a room temperature (the manufacture method of the gallium nitride system semiconductor light emitting device concerning the gestalt of the 2nd operation). However, when temperature of the silicon on sapphire 100 at the time of forming the ITO film 800 is made into a room temperature, since the ITO film 800 formed becomes opaque, heating as a production process is needed the back for carrying out the rarefaction of the ITO film 800. After this, it will crystallize and a production process will become transparence, if grade heat-treatment of the temperature of silicon on sapphire 100 is carried out for 10 minutes at about 300 degrees C into an air ambient atmosphere. If an air ambient atmosphere is changed and lowered on a nitrogen-gas-atmosphere mind after carrying out the rarefaction, a film with more small specific resistance will be obtained.
[0028] In addition, by the manufacture method concerning the gestalt of this 2nd operation, since the production process until it forms the ITO film 800 is the same as that of the manufacture method concerning the gestalt of the 1st operation mentioned above, explanation for the second time is omitted.
[0029] It was checked that the specific resistance of the ITO film 800 of the gallium nitride system semiconductor light emitting device manufactured by such manufacture method concerning the gestalt of the 2nd operation has become below 0.0005-ohmcm. And when the same N type electrode 910 as what was mentioned above, and the P type electrode 920 were formed, operating voltage was very as low as 3.5V with 20mA current, and improving about 60% rather than the translucent auxiliary electrode with which the ejection effectiveness to the exterior of light also consists of the conventional nickel/Au thin film was checked. It is the same as that of the thing of the manufacture method which also mentioned this point above.
[0030] In addition, by the manufacture method concerning the gestalt of this 2nd operation, in order to form the ITO film 800 at a room temperature, there is an advantage that the pattern formation in the lift off using a photoresist becomes possible. In addition, although it is necessary by the manufacture method concerning the gestalt of the 1st operation to form a pattern with means, such as etching, after formation of the ITO film 800 since a photoresist deteriorates with heating, and pattern formation in lift off cannot be performed, the heating production process for carrying out the rarefaction of the ITO film 800 becomes unnecessary. Since the quality ITO film 800 can be formed by any method, it is desirable to choose a method from balance with the effect of the heat to the production process and other portions of order, a chemical, etc.
[0031] Since the production process until the manufacture method of the gallium nitride system semiconductor light emitting device concerning the gestalt of operation of the 3rd of this invention forms the ITO film 800 is the same as that of the manufacture method concerning the gestalt of the 1st operation mentioned above, explanation for the second time is omitted.
[0032] By the manufacture method concerning the gestalt of this 3rd operation, the ITO film 800 is formed in 2 steps. That is, about 0.5-micrometer top ITO film 820 is formed by the sputtering method on about 100A bottom ITO film 810 formed with the vacuum deposition method.
[0033] It was checked that the specific resistance of the ITO film 800 of the gallium nitride system semiconductor light emitting device manufactured by this method has become below 0.0002-ohmcm. And when the same N type electrode 910 as what was mentioned above, and the P type electrode 920 were formed, operating voltage was very as low as 3.4V with 20mA current, and improving about 60% or more rather than the translucent auxiliary electrode with which the ejection effectiveness to the exterior of light also consists of the conventional nickel/Au thin film was checked.
[0034] Thus, if an ITO film is formed only by the sputtering method, a good current diffusion layer will not be formed, but if it is the ITO film of the two-layer structure by the sputtering method after a vacuum deposition method and a vacuum deposition method, the reason used as a good thing can be considered to be the following.
[0035] That is, by the sputtering method, since the Mg dope GaN layer 600 by which Mg was doped is exposed to the high energy condition of the plasma, it thinks for a crystal defect to arise, consequently for the surface of the Mg dope GaN layer 600 to form high resistance. Moreover, from the surface of the Mg dope GaN layer 600 which is a P type Ga layer, the hydrogen ion in the

plasma can invade and for forming high resistance can also be thought.
[0036] On the other hand, in a vacuum deposition method, the particle of an energy state far lower than the sputtering method only collides, and, moreover, a hydrogen ion does not exist, either. For this reason, it thinks that a good current diffusion layer is formed since high resistance-ization of the surface of the Mg dope GaN layer 600 etc. does not arise, and is ******. Especially, by the ITO film 800 of two-layer structure, in order to form the bottom ITO film 810 with a vacuum deposition method previously, even if it forms the top ITO film 820 by the sputtering method, in order to prevent invasion to the interior of the plasma of the bottom ITO film 810, it thinks for the crystal defect of the surface of the Mg dope GaN layer 600 etc. not to arise.
[0037] from this consideration, the Mg dope GaN layer 600 which is a P type GaN layer about the particle of a high energy condition like the plasma is not directly hit in formation of the ITO film 800 — it needs — it is thought that what is necessary is just to carry out. Therefore, it is thought that you may be not the vacuum deposition method that not necessarily heats the source of vacuum evaporationo with an electron gun but the laser ablation method and a CVD method.
[0038] Since the production process until the manufacture method of the gallium nitride system semiconductor light emitting device concerning the gestalt of operation of the 4th of this invention forms the ITO film 800 is the same as that of the manufacture method concerning the gestalt of the 1st operation mentioned above, explanation for the second time is omitted.
[0039] Formation of the ITO film 800 in this method was performed with the sol gel process. That is, it considered as about 1 micrometer of thickness, and burning temperature was made into 550 degrees C, and firing time was made into 1 hour. It was checked that the specific resistance of the ITO film 800 manufactured by this sol-gel method has become below 0.005-ohmcm. This is larger than the vacuum deposition and the sputtering method which were mentioned above a little. When the same N type electrode 910 as what was mentioned above, and the P type electrode 920 were formed, operating voltage was fully as low as 3.6-4.0V with 20mA current, and improving about 50% or more rather than the translucent auxiliary electrode with which the ejection effectiveness to the exterior of light also consists of the conventional nickel/Au thin film was checked.
[0040] In addition, in the case of this sol gel process, the good ITO film 800 is not formed as burning temperature is 400 degrees C or less. Moreover, there is also a trouble that it is inferior to repeatability from the method by vacuum deposition or the sputtering method.
[0041] In addition, although the ITO film 800 is used as a transparence electric conduction film with the gestalt of four operations, there is nothing that were mentioned above and for which this invention is limited to this. For example, in the gestalt of the 2nd operation, ZnO whose thickness is about 100A, and SnO2 are formed with a vacuum deposition method instead of the bottom ITO film 810, and it is SnO2 on it. It is possible to form about 0.5 micrometers of 10% of top ITO films 820 with a vacuum deposition method. in this case, operating voltage — 0.1-0.2 — it only increased about V and it is checked in the experiment that it is completely satisfactory practically. In addition, ZnO and SnO2 which were formed instead of the bottom ITO film 810 in this experiment Since it has not doped at all, in ZnO, they are SnO(s)2, such as aluminum. If suitable doping of Sb etc. is performed to a case, it will be thought that what has the operating voltage which is not different from the usual ITO film 800 is made.
[0042]
[Effect of the Invention] The gallium nitride system semiconductor light emitting device concerning this invention has the current diffusion layer which consists of a transparence electric conduction film by which the eye was further formed at least by methods other than the sputtering method on the P type GaN semiconductor layer in a gallium nitride system semiconductor light emitting device.
[0043] It is checked that the gallium nitride system semiconductor light emitting device which has the current diffusion layer which consists of a transparence electric conduction film formed by methods other than the sputtering method has fully low operating voltage, and the ejection effectiveness of light is also higher than the conventional thing.
[0044] Moreover, as methods other than said sputtering method, either a vacuum deposition method, the laser ablation method or a sol gel process is desirable. That is, either the vacuum deposition method which is a method of not making a P type GaN semiconductor layer generating a crystal defect etc., the laser ablation method or a sol gel process is desirable.
[0045] Moreover, as for said current diffusion layer, it is desirable to consist of either an ITO film, a tin oxide film, an indium oxide film or a zinc-oxide film.
[0046] Said especially current diffusion layer is the ITO film in which the eye was formed by the vacuum deposition method much more at least, and this ITO film is SnO2. It is desirable that it is 2 - 20%.
[0047] When the eye was further formed with the vacuum deposition method and the thickness was made into 100A or more, even if operating voltage was low even if it formed the bilayer eye or subsequent ones by the sputtering method further on it, and it was under environment wherever [mechanical-strength or high-humidity/temperature], it has checked that it was the thing of said transparence electric conduction film excellent in endurance.

[Translation done.]

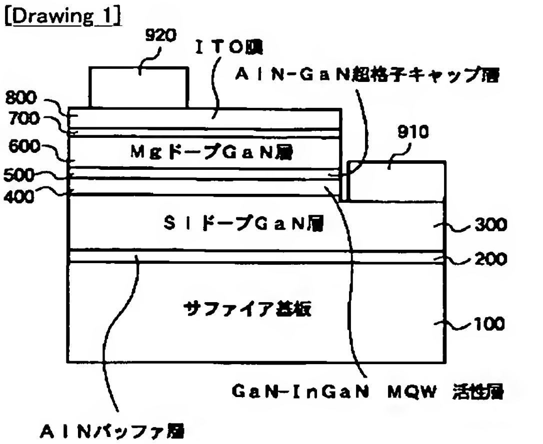
DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the rough cross section of the gallium nitride system semiconductor light emitting device concerning the gestalt of operation of the 1st of this invention.
[Drawing 2] It is the rough cross section of the gallium nitride system semiconductor light emitting device concerning the gestalt of operation of the 2nd of this invention.
[Description of Notations]
100 Silicon on Sapphire
200 AlN Buffer Layer
300 Si Dope GaN Layer
400 Barrier Layer
500 Cap Layer
600 Mg Dope GaN Layer
700 Zn Layer
800 N Type Electrode
900 P Type Electrode

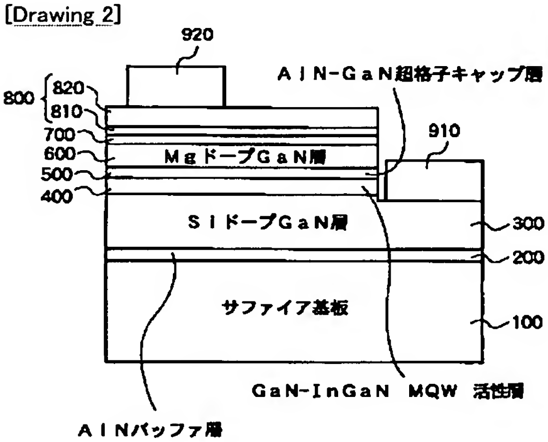
[Translation done.]

DRAWINGS

[Drawing 1]



[Drawing 2]



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